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	Engineering and Design DRAINAGE LAYERS FOR PAVEMENTS	
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CEMP-ET

Engineer Technical
Letter 1110-3-435

1 May 1992

Engineering and Design
DRAINAGE LAYERS FOR PAVEMENTS

1. Purpose. This letter updates guidance for design and construction of subsurface drainage features for Army and Air Force pavements. The guidance supersedes that portion of the guidance provided in TM 5-820-2/AFM 88-5, Chapter 2 for design of subsurface drainage layers in pavements (Chapter 6) and provides guidance for all pavements located in both frost and nonfrost areas. The use of the guidance for flexible pavement roads, streets, or parking areas having a structural thickness less than 8 in. is optional.

2. Applicability. This letter is applicable to all HQUSACE elements, major subordinate commands, districts, laboratories and field operating activities (FOA) having Army and Air Force military construction design responsibility.

3. References.

a. TM 5-818-2/AFM 88-6, Chap. 4, Pavement Design for Seasonal Frost Conditions.

b. TM 5-820-2/AFM 88-5, Chap. 2, Drainage and Erosion Control: Subsurface Drainage Facilities for Airfields.

c. TM 5-822-2/AEM 88-7, Chap. 5, General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Areas.

d. TM 5-822-5/AFM 88-7, Chap. 3, Flexible Pavement for Roads, Streets, Walks, and Open Storage Areas.

e. TM 5-822-6/AFM 88-7, Chap. 1, Rigid Pavements for Roads, Streets, Walks, and Open Storage Areas.

f. TM 5-825-2/AFM 88-6, Chap. 2, Flexible Pavement Design for Airfields.

g. TM 5-825-3/AFM 88-6, Chap. 3, Rigid Pavements for Airfields.

4. Background. Research conducted at the US Army Engineer Waterways Experiment Station (WES), The Construction Engineering Research Laboratories (CERL), and the Cold Regions Research and

Engineering Laboratory (CRREL) has shown that bases and subbases for military pavements constructed to meet Corps of Engineers density and gradation criteria are virtually impermeable. In a study conducted for CERL, Mr. Harry R. Cedergren concluded that most airfield pavements have poor subsurface drainage and that joint and surface sealing and repair programs are not able to keep surface water out of the structural sections. Based on extensive literature reviews and field surveys, it has been found that the permeability of a good drainage layer should be in the order of 1,000 to 10,000 ft/day. To ensure military pavements have adequate drainage, the criteria provided in the enclosed technical guidance is to be used for design and construction of subsurface drainage aspects of pavements.

5. Action to be Taken. The guidance in Enclosures 1 and 2 should be used for design and construction of the subsurface drainage layers for all Army and Air Force pavements.

FOR THE DIRECTOR OF MILITARY PROGRAMS:

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TECHNICAL GUIDANCE FOR DESIGN OF THE SUBSURFACE DRAINAGE FOR MILITARY PAVEMENTS

1. Introduction. Except in frost areas, the current design criteria for military pavements, as given in Th 5-822-S/AFM 88-7, Chap. 3; TM 5-822-2/ AFM 88-7, Chap. 5; TM 5-825-3/AFM 88-6, Chap 3; and Th 5-825-2/AFM 88-6, Chap. 2, are based on the assumption that the base and subbase layers will be adequately drained, i.e., the criteria do not consider damage because of free water at layer interfaces nor for a loss of material strength caused by pore pressures induced by traffic. To ensure adequate subsurface drainage, major changes to the criteria for design of subsurface facilities (TM 5-820-2/ AFM 88-5, Chap. 2 and TM 5-818-2/AFM 88-6, Chap. 4) are being implemented. The changes involve modifying the gradation for base materials, requiring a drainage layer for most pavements, adding procedures for design of the drainage layers, limiting the time for drainage of the base, and supersedes the guidance in TM 5-818-2/AFM 88-6 for a free draining base in frost areas.

2. Definitions.

a. Drainage Layer. A drainage layer is a layer in the pavement structure that is specifically designed to allow horizontal drainage of water from the pavement structure. The layer is also considered to be a structural component of the pavement and will serve as part of the base or subbase. The drainage layer will consist of either a rapid draining material or an open graded material and will be designed by criteria provided in this Engineer Technical Letter(ETL).

b. Separation Layer. A separation layer is a layer provided directly beneath the drainage layer to prevent fines from infiltrating or pumping into the drainage layer and to provide a working platform for construction and compaction of the drainage layer. Generally, a minimum of 4 in. of dense-graded aggregate material is used; however, a filter fabric can be used. The material for the granular separation layer should meet the requirements for a 50 CBR subbase as given in Th 5-822-5/AFM 88-7, Chap. 3 and Th 5-825-2/ AFM 88-6, Chap. 2. The requirements for filter fabric are given in TM 5-820-2/ AFM 88-5, Chap. 2.

c. Rapid Draining Material (RDM). A rapid draining material is a material having a sufficiently high permeability (1,000 to 5,000 ft/day) to serve as a drainage layer and will also have the stability to support construction equipment and the structural strength to serve as a base and/or a subbase. Gradation limits for the RDM are given in Table 1, and the design properties are given in Table 2. To ensure adequate stability and strength, the uniformity coefficient (C~) of the RDM should be greater than 3.5.

d. Open Graded Material (OGM). An open graded material is a material having a very high permeability (greater than 5,000 ft/day) which may be used for a drainage layer. Such a material will normally require stabilization for construction stability or for structural strength to serve as a base in a

flexible pavement. Gradation limits for the OGM are given in Table 1, and the design properties are given in Table 2.

Table 1

Gradations of Materials for Drainage Layers and Choke Stone

Sieve Designation	Drainage Layer Material: Rapid Draining Material	Drainage Layer Material: Open Graded Material	Choke Stone
1-1/2 in.	100	100	100
1 in.	70-100	95-100	100
3/4 in.	55-100	--	100
1/2 in.	40-80	25-80	100
3/8 in.	30-65	--	80-100
No. 4	10-50	0-10	10-100
No. 8	0-25	0-5	5-40
No. 16	0-5	--	0-10

Table 2

Properties of Materials for Drainage Layers

Property	Rapid Draining Material	Open Graded Material
Permeability ft/day	1;000-5,000	>5,000
Effective Porosity	0.25	0.32
Percent Fractured	90% for 80 CBR	90% for 80 CBR
Faces (COE method)	75% for 50 CBR	75% for 50 CBR
C_v	>3.5	--
LA Abrasion	<40	<40

Note: C_v is the uniformity coefficient = D_{60}/D_{10}.

e. Choke Stone. A choke stone is a small size stone used to stabilize the surface of an OGM. The choke stone should be a hard, durable, crushed aggregate having 90 percent fractured faces. The ratio of D_{15} of the coarse aggregate to the D_{15} of the choke stone must be less than 5, and the ratio of the D_{50} of the coarse aggregate to D_{50} of the choke stone must be greater than 2. The gradation range for acceptable choke stone is given in Table 1. Meeting the requirements of a choke stone would be either the ASTM No. 8 or ASSHO No. 9 stone.

f. Coefficient of Permeability. The coefficient of permeability is a measure of the rate at which water passes through a unit area of material in a given amount of time under a unit hydraulic gradient.

g. Effective Porosity. The effective porosity is defined as the ratio of the volume of voids that will drain under the influence of gravity to the total volume of a unit of aggregate. The difference between the porosity and the effective porosity is the amount of water that will be held by the aggregate. For materials such as the RDM and OCM, the water held by the aggregate will be small; thus, the difference between the porosity and effective porosity will be small (less than 10 percent). The effective porosity may be estimated by computing the porosity from the unit dry weight of the aggregate and the specific gravity of the solids which then should be reduced by 5 percent to allow for water retention on the aggregate.

h. Stabilization. Unless experience indicates otherwise, stabilization of OGM is required for stability and strength, and for preventing degradation of the aggregate in handling and compaction. Stabilization may be accomplished mechanically by use of a choke stone or by the use of a binder such as asphalt or cement. The choke stone will be used only with the OGH and will be referred to as a choked OGM. The asphalt or cement may be used with the OGM and will be referred to as an asphalt or cement stabilized OGM. Stabilization of the CGM is accomplished by using only enough asphalt or cement paste required to coat the aggregate. Care should be taken so that the voids are not filled by excess stabilizer. The stabilization material predominantly used is asphalt cement (AC-20) at 2 to 2-1/2 percent (by weight) for the OGH. Higher asphalt cement percentages are required when a less open graded material is used. For example, New Jersey's asphalt cement stabilized permeable base gradation requires 3 percent asphalt cement to coat the aggregates. For additional asphalt stabilized permeable base stability, a stiffer asphalt cement, such as an AC-40, should be used. Portland cement at 1-1/2 to 3 bags/cu yd has also been used. As with asphalt cement stabilized permeable base, the amount of portland cement per cubic yard will depend on the voids and surface area of the aggregate in the permeable material. For example, California uses not less than 282 lb of portland cement per cubic yard with a water-cement ratio of 0.37. The permeability of this material is approximately 4,000 ft/day. Whereas, Wisconsin with a more open material (permeability approximately 10,000 ft/day) has found that 200 lb of portland cement per cubic yard and a water-cement ratio of 0.37 provide adequate strength, durability, and stability.

i. Degree of Drainage. The degree of drainage is the ratio of water that has drained from a material to total amount of water that the material is capable of holding.

3. Drainage Criteria.

a. Concepts. For pavements in nonfrost areas and having a subgrade with a permeability greater than 20 ft/day, one can assume that the vertical drainage will be sufficient such that no drainage layer is required. Also, flexible pavements in nonfrost areas and having a total thickness of 8 in. or less are not required to have a drainage layer. For pavements requiring drainage layers, the design of the drainage layer shall be based on the premise that the capacity of the drainage layer should be greater than the volume of water entering the pavement, and that the drainage layer, if saturated, should reach a degree of drainage of 0.85 within 1 day after the inflow of water stops. The degree of drainage for the drainage layer is defined as the volume of water that has drained from the layer over a specified time period divided by the total volume of water in the layer that can be drained by gravity.

b. Design Water Inflow. The subsurface drainage of the pavement is to be designed to handle water infiltration through the pavement from a design storm index for a design storm of 1 hr duration at an expected return frequency of 2 years. For the continental United States, this can be determined from Figure 1 (taken from Th 5-820-1/AFM 88-5, Chap. 1). Guidance for determining the design storm for other parts of the world is also given in Th 5-820-1/ AFM 88-5, Chap. 1. The inflow is determined by multiplying the design rainfall index CR in inches per hour) times an infiltration coefficient F. This coefficient will vary over the life of the pavement depending on the type of pavement, surface drainage, pavement maintenance, and structural condition of the pavement. Since the determination of a precise value of the infiltration for a particular pavement is very difficult, a value of 0.5 may be assumed for design. The value of the coefficient may be changed based on local experience and anticipated inflow rates for a particular pavement. The rate of water inflow (q in cubic feet per foot width of drainage path per hour) is then computed by the equation

$$q - L \times F \times (R/12) \qquad \text{(eq 1)}$$

where

L = length of the drainage path in feet
F = infiltration coefficient
R = design rainfall index in inches per hour

It should be noted that the drainage layer design is based only on the infiltration of water from the surface. Normally, other sources would provide

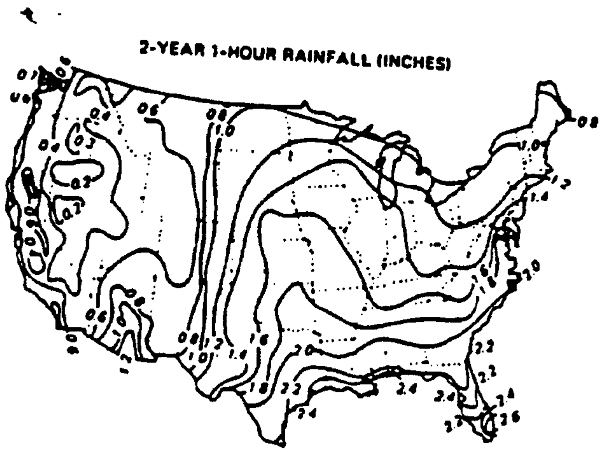


Figure 1. Design Storm Index, 1-hr Rainfall Intensity-Frequency Data for Continental United States Excluding Alaska (Chart reproduced from US Weather Bureau, Technical Paper No. 40, Rainfall Frequency Atlas of The United States, Washington, DC, May 1961.)

water to the drainage layer but such water would be minor and would not be a consideration in the design of the drainage layer. Should ground water be present in any substantial quantities, special provisions should be made to intercept and drain the water before it reaches the drainage layer. The drainage layer is expected to aid in draining of water in the subbase and subgrade caused by frost action, but this volume of water will not be considered in computing the design water inflow.

c. <u>Length and Slope of Drainage Path.</u> The length of drainage path is measured along the slope of the drainage layer from the crest of the slope to where the water will exit the drainage layer. In simple terms, the length of the drainage path is the maximum distance water will travel in the drainage layer. The length of drainage path (L) in feet may be computed by the equation

$$L = \frac{X\sqrt{i_t^2 + i_e^2}}{i_t} \qquad \textbf{(eq 2)}$$

where

X = the length in feet of the transverse slope of the drainage layer

i_t = the transverse slope of the draining layer
i_e = the longitudinal slope of the drainage layer

The slope (i) of the drainage path may be computed by the equation

$$i = \sqrt{i_t^2 + i_e^2} \qquad \text{(eq 3)}$$

d. Capacity of Drainage Layer. The capacity of the drainage layer (Q in cubic feet per foot width of pavement) is computed based on the effective porosity (n~) and the volume of water draining from the drainage layer during the 1 hr of water inflow. Since the criterion is for a degree of drainage of 0.85 within 24 hr, it is to be assumed that only 85 percent of the voids will be available for storage of water. Thus, the capacity of the drainage layer may be computed by the equation

$$Q = (0.85)\ (n_e)\ (H)\ (L) + (k/24)\ (t)\ (i)\ (H)/2 \qquad \text{(eq 4)}$$

where

Q = capacity of the drainage layer in cubic feet/feet
n_e = effective porosity
H = thickness of the drainage layer in feet
L = length of the drainage path in feet
k = permeability of the drainage layer. in feet/day
t = 1 hr (length of design storm)
i = slope of the drainage path in feet/foot

e. Thickness of Drainage Layer. By setting Q - q and substituting equations 1 and 4 for q and Q, the minimum thickness in feet of the drainage layer required to provide the storage capacity for a 1 hour design storm is determined from the equation

$$H = 4\ F\ R\ L/[40.8\ n_e\ L + ki) \qquad \text{(eq 5)}$$

If the term (ki) is small compared to the term ($40.8 n_e L$) which would probably be the case for long drainage paths (> 20 ft), then the required thickness of the drainage layer can be estimated by deleting the term (ki) from equation 5 or

$$H = (F\ R)/(10.2\ n_e) \qquad \text{(eq 6)}$$

The value of H obtained from equation 6 will always be somewhat greater than the value of H determined from equation 5. In no case should the thickness of the drainage layer be less than 4 in.

f. Time for Drainage. The time for drainage of the drainage layer is a function of effective porosity, length of the drainage path, thickness of the drainage layer, slope of the drainage path, and permeability of the drainage layer. This function has been solved in terms of time factor TF and a parameter m. The time factor is obtained from Figure 2 as a function of the parameter s which is determined by the equation

$$s = Li/(H) \qquad \text{(eq 7)}$$

After determining the time factor TF from Figure 2, the time required to obtain a degree of drainage of 0.85 is computed from

$$T_{85} = (TF)(m) \qquad \text{(eq 8)}$$

where

T_{85} = time in days required to obtain a degree of drainage of 0.85
m = a parameter defined as

$$(n_e\ L^2)/(k\ H) \qquad \text{(eq 9)}$$

g. Design Example. Assume the following design parameters are appropriate for a large parking lot.

The design rainfall (R) = 2.0 in.

The effective porosity (n_e) = 0.2

The length of the drainage path (L) = 150 ft

The permeability of the drainage material (k) = 2,000 ft/day

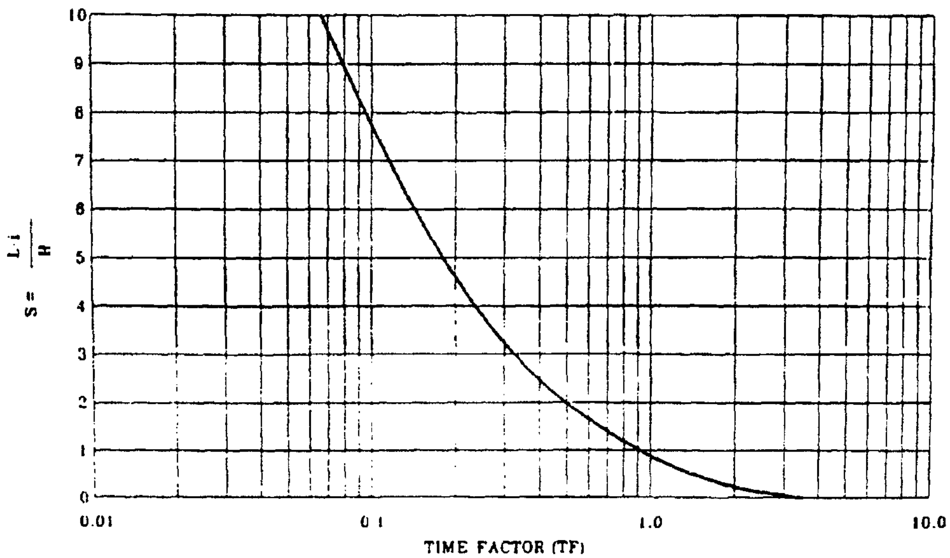


Figure 2. Time Factor for 85 Percent Drainage

The slope of the drainage path (i) = 0.01

The infiltration coefficient (F) = 0.5

First the thickness, H, of the drainage layer required to provide the necessary storage capacity is computed by substituting into equation 5 as follows

$$H = [4(0.5)(2.0)\ (150)]/[40.8(0.2)\ (150) + (0.01)\ (2{,}000))$$

$$H = 0.48 \text{ ft. or } 5.8 \text{ in.}$$

Rounding the computed thickness up to the next full inch gives a design thickness of 6 in. Equation 6 could have been used to estimate the thickness as follows

$$H = F\ R/10.2\ n_e = [(0.5)\ (2)]/[(10.2)\ (0.2)] = 0.49 \text{ ft}$$

Again the thickness would round up to 6 in. The next step would be to use Figure 2 to determine the time to obtain a degree of drainage of 0.85. Using equation 7 the value of s is computed to be 3.0 and from equation 9 the value of m is computed to be 4.5. From Figure 2 the time factor, TF, is found to be 0.32. The time to obtain a degree of drainage of 0.85 is computed from equation 8.

$$T_{85} = (TF)(m) = (\ 0\ 32)\ (4.5) = 1.44 \text{ days}$$

Since 1.44 days is considerably greater than the 1 day allowed by the criteria, the design must be modified to obtain a shorter time for drainage. The parameter that can be changed will depend on the particular design situation but for this example assume the design can be modified to obtain a drainage path of 100 ft. The thickness required for storage is found from equation 5 to be 6 in. The s parameter for entering Figure 2 is now 2.0 which gives a time factor, TF, of 0.5. The m parameter is computed from equation 8 to be 2.0. Equation 7 is again used to compute T_{85}.

$$T_{85} = (TF)(m) = (0.5)\ (2.0) = 1 \text{ day}$$

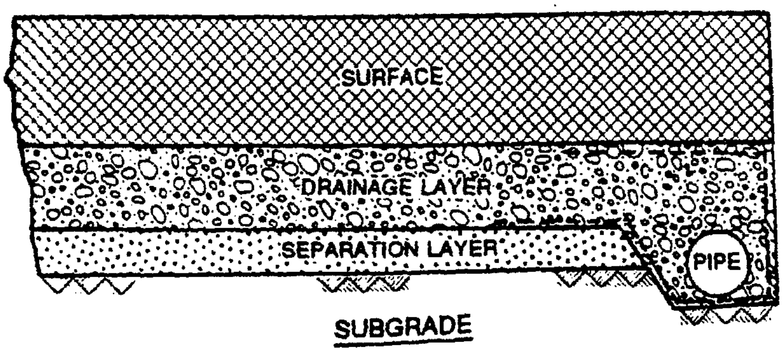
The 1 day required for drainage meets the criteria; thus, the design would call for a 6-in. drainage layer with a 100-ft drainage path.

4. Placement.

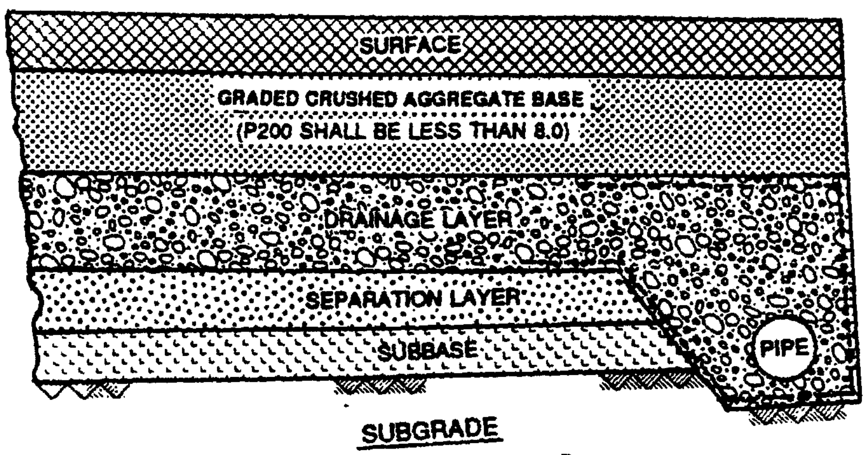
a. Rigid Pavements. In the case of rigid pavements the drainage layer, if required, shall be placed as shown in Figure 3a directly beneath the concrete slab. In the structural design of the concrete slab the drainage layer along with any granular separation layer shall be considered a base layer, and structural benefit may be realized from the layers.

b. Flexible Pavements. In the case of flexible pavements the drainage layer should be placed either directly beneath the surface layer as shown in Figure 3a or beneath a graded crushed aggregate base course as shown in Figure 3b. If the thickness of granular subbase is equal to or greater than the thickness of the drainage layer plus the thickness of the separation layer. the drainage layer is placed beneath the graded crushed aggregate base (Figure 3b). Where the total thickness pavement structure is less than 12 in., the drainage layer may be placed directly beneath the surface layer (Figure 3a) and the drainage layer would serve as the base. When a graded crushed aggregate base is used above the drainage layer, care must be taken to limit the material passing the No. 200 sieve in the graded crushed aggregate base to 8 percent or less. These precautions are necessary to provide adequate drainage and to ensure that an excess of fines will not be available to wash into the drainage layer. Should a graded aggregate base not be available, then it is suggested that an asphalt stabilized base be used above the drainage layer. In areas where frost will penetrate the base, the base must also meet the criteria in Th 5-818-2/AFM 88-6, Chap. 4 for a nonfrost susceptible material.

5. Separation layer. The drainage layer must be protected from contamination of fines from the underlying layers by a separation layer to be placed directly beneath the drainage layer. In most cases the separation layer should be a graded aggregate material meeting the requirements of a 50 CBR subbase. The minimum thickness for the separation layer is 4 in. A granular separation layer provides a firm foundation for compaction of the drainage layer and adds strength to the pavement structure. For design situations where a firm foundation already exists and the thickness of the separation layer is not needed in the structure for protection of the subgrade, a filter



3a. Placed Under Surface



3b. Placed Under Base

Figure 3. Drainage Layer Placement

fabric may be substituted for the granular separation layer. The fabric must meet the requirements specified in Th 5-820-2/AFM 88-5, Chap. 2.

6. Material Properties.

a. Strength and Durability. The material for a drainage layer should be a hard, durable crushed aggregate. Crushed aggregate meeting the gradation requirements of the RDM will provide sufficient stability for the drainage layer on which construction equipment such as dump trucks, transit trucks, and tracked pavers can operate.

b. Material Permeability. The permeability of the drainage layer is primarily a function of the material gradation and density. For a given gradation, it is important for strength considerations to obtain the maximum possible density during compaction without crushing the aggregate. Thus, the permeability is controlled by controlling the gradation. Table 2 provides estimates for the permeability of RDM and OCM that are applicable to the gradation of the in-place material. There should be very few design situations requiring drainage materials having permeabilities greater than 5,000 ft/day; thus, the OCM will almost always meet the permeability requirements. For RDM, a permeability of 2,000 ft/day may be used for design. If the required permeability is between 2000-5000 ft/day the RDM may be used provided the RDM is restructured to the coarse side of the gradation band. This value or laboratory determined permeability value may be used as estimates of the in-place permeabilities until local experience with construction of drainage layers can establish the in-place permeabilities being obtained.

7. Construction.

a. Experience. Without properly trained personnel, construction of the drainage layer can cause problems. Experience with highly permeable bases (drainage layers) both by the Corps of Engineers and various State Departments of Transportation indicates that pavements containing such layers can be constructed without undue difficulties provided certain guidelines are followed. These guidelines are discussed below.

b. Placement. The material for the drainage layer must be placed in a manner to prevent segregation and to obtain a layer of uniform thickness. The materials for the drainage layer will require extra care in stockpiling and handling. Placement of the RDK and OGM is best accomplished using an asphalt concrete paver. To ensure good compaction, the maximum lift thickness should be no greater than 6 in. If choke stone is used to stabilize the surface of OCM, the choke stone is placed after compaction of the final lift of OCM. The choke stone is spread in a thin layer no thicker than ½ in. using a spreader box or paver. The choke stone is worked into the surface of the OCM by the use of a vibrator roller and by wetting. The choke stone remaining on the surface should not migrate into the OCM by the action of water or traffic.

c. <u>Proof Rolling.</u> For Army Class IV and Air Force heavy, modified heavy, and medium load flexible airfield pavements. proof rolling as per TM 5-825-2/ AFM 88-6 Chap. 2, is required on the graded crushed aggregate base even when used over a drainage layer. Proof rolling the separation layer prior to placement of the drainage layer for other pavements is recommended. For other Air Force flexible pavements and Army Class III flexible pavements, it is recommended that the proof rolling be accomplished using a rubber-tired roller with each tire loaded to 20,000 lb or more and inflated to at least 90 lb/ sq in. A minimum of six coverages should be applied where a coverage is the application of one tire print over each point in the surface of the designated area. For rigid pavements and flexible pavements for roads, streets, parking lots and Class I and II Army airfields, proof rolling of the separation layer may be accomplished using the rubber-tired roller described above or by using a truck having tandem axles with either dual tires or super single tires. The truck should be loaded to provide 20,000 lb per axle. During proof rolling, action of the separation layer must be monitored for any sign of excessive movement or pumping that would indicate soft spots in the separation layer or the subgrade. Since the successful placement of the drainage layer depends on the stability of the separation layer, all weak spots must be removed and replaced with stable material. All replaced material must also be proof rolled as specified above.

d. <u>Compaction</u>. Compaction is a key element in the successful construction of the drainage layer. Compaction control normally used in pavement construction is not appropriate for materials such as the RDK and OGM. It is therefore, necessary to specify compaction techniques and level of effort instead of the properties of the end product. It will be important to place the drainage material in relatively thin lifts (6 in. or less) and to have a good firm foundation beneath the drainage material. The recommended method of determining the required compaction effort is to construct a test section and closely monitor the aggregate during compaction to determine when crushing of the aggregate appears excessive. Experience has indicated that sufficient compaction can be obtained by six passes or less of a 10-ton vibrator roller. Material not being stabilized with asphalt or cement should be kept moist during compaction. Asphalt stabilized materials for the drainage layer must be compacted at a somewhat lower temperature than a dense-graded asphalt material. In most cases it will be necessary to allow an asphalt stabilized material to cool to less than 200~ F before compaction. After compaction, the drainage layer should be protected from contamination by fines from construction traffic or from flow of surface water. It is recommended that the surface layer be placed as soon as possible after placement of the drainage layer. Precautions must also be taken to protect the drainage layer from disturbance by construction equipment. Only tracked asphalt pavers should be allowed for paving over any RDM or OGM that has not been stabilized. Drivers should avoid rapid acceleration, hard braking, or sharp turning on the completed drainage layer.

e. In-place Permeability. The permeability of an RDM can easily be reduced to an unacceptable level by over compaction or contamination with fines. The in-place RDM should easily accept the inflow of water without ponding or flowing across the surface. In-place permeability tests for materials as open as the RDM are difficult to run but may be conducted to get estimates of the in-place permeability. laboratory permeability tests may be conducted, but care must be taken to ensure that the laboratory samples are representative of the in-place material. In laboratory tests the permeability is normally measured in the direction of compaction, whereas, in the drainage layer the water flow is perpendicular to the direction of compaction. If such is the case, the field permeability may be an order of magnitude higher than the laboratory permeability.

8. Collector Drains.

a. Design Flow. It is absolutely essential that all pavements having drainage layers be provided with collector systems as specified in TM 5-820-2/ AFM 68-S, Chap. 2, such that positive relief of water from the pavement will be provided. The collector system should have the capacity to handle the water from the drainage layer plus water from other sources. The volume of water entering the collector system from the drainage layer is computed assuming the drainage layer is flowing full. Thus, the volume of water (Qo) in cubic feet per day per foot of length of collector (assuming the drainage layer is only on one side of the collector) would be

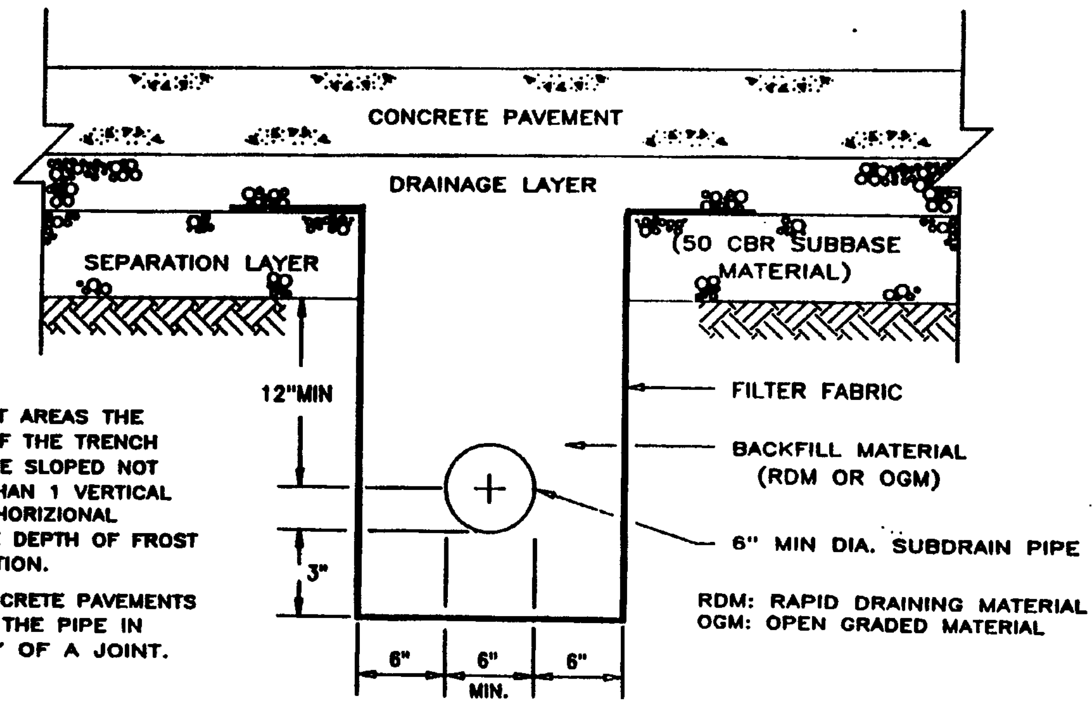
$$Qo = H \times I \times k \qquad \text{(eq 10)}$$

where

H = thickness of the drainage layer in feet
I = slope of the drainage layer in feet/feet
k = permeability of the material in the drainage layer in feet/day

If the collector system has water entering from both sides, the volume of water entering the collector would be double that given by equation 10.

b. Collector Pipe. The collector pipe may be perforated flexible, ABS, corrugated polyethylene or smooth rigid polyvinyl chloride pipe. The minimum size pipe that is to be used for a collector pipe is 6 in. and the mid height of the pipe is to be located a minimum of 12 in. below the separation layer. The backfill material around the collection pipe is to an OCM (or RDM provided the drain layer is RDM) and is to be protected from infiltration of fines by a filter fabric. In areas where frost is predicted to penetrate to the depth of the collector trench and differential heave would cause problems, the sides of the trench above the depth of frost penetration shall be sloped not steeper than 1 vertical on 10 horizontal. Typical details for



NOTE: 1) IN FROST AREAS THE SIDES OF THE TRENCH SHALL BE SLOPED NOT MORE THAN 1 VERTICAL ON 10 HORIZIONAL FOR THE DEPTH OF FROST PENTRATION.

2) FOR CONCRETE PAVEMENTS LOCATE THE PIPE IN VICINITY OF A JOINT.

Figure 4. Typical Concrete Pavement Interior Subdrain Detail

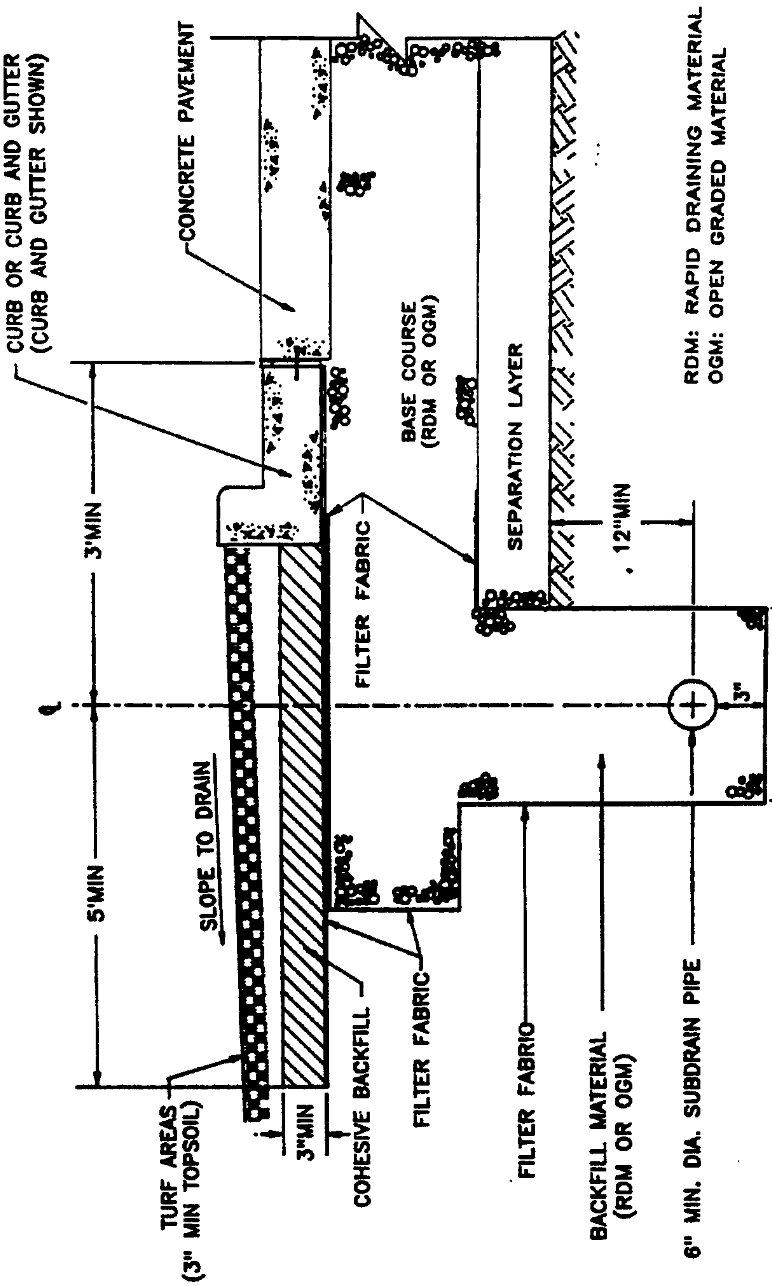


Figure 5. Pavement Edge Subdrain for Concrete Pavements

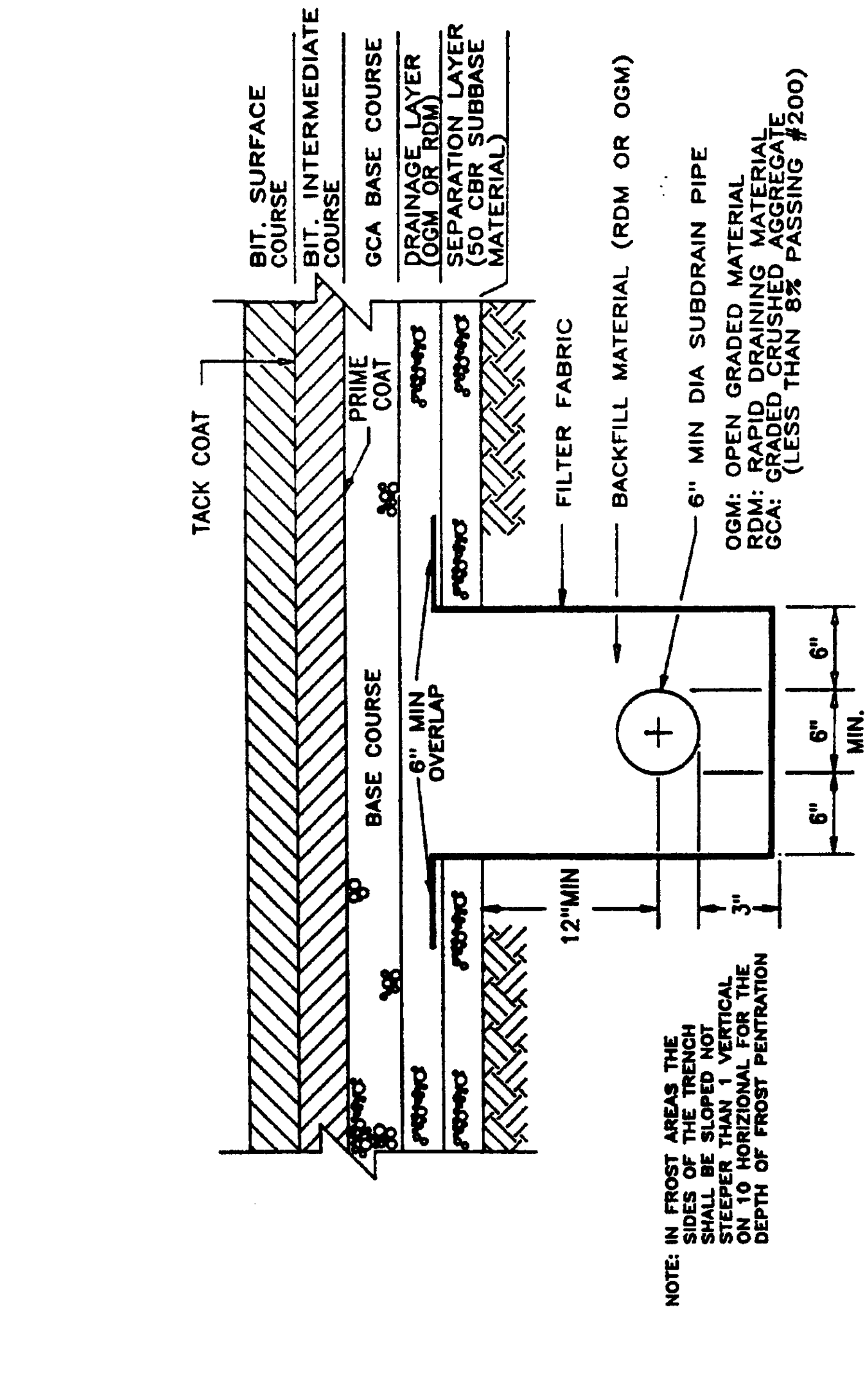


Figure 6. Typical Bituminous Pavement Interior Subdrain Detail

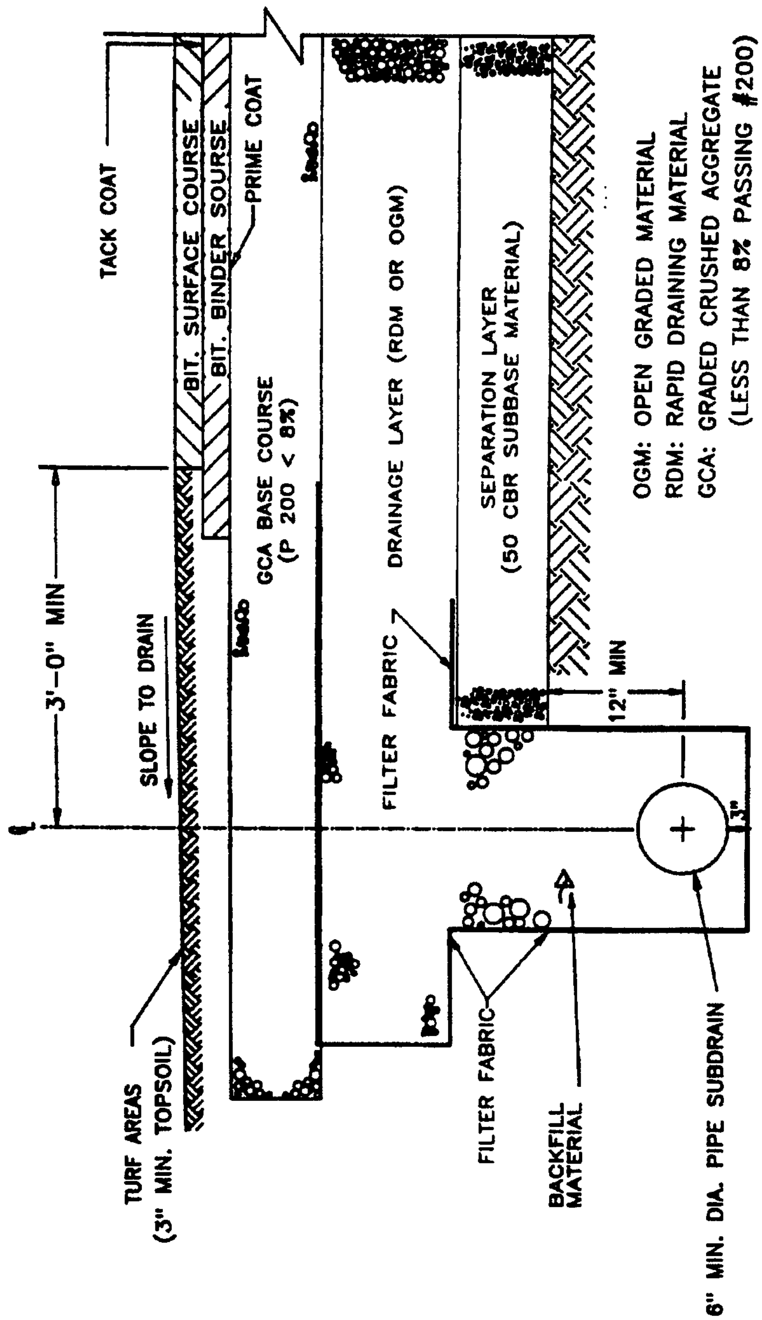


Figure 7. Typical Pavement Edge Subdrain for Bituminous Pavements

installation of the collector system are given in Figures 4, 5, 6, and 7. Note that the details given in these figures are only typical details and should not be taken as being mandatory. Normally, the collector pipes are to be located along the edge of the pavements but for parking lots, airfield aprons, or other pavements which would have long drainage distances the collector pipes may be located under the pavement.

c. lateral Outlet Pipe. In most installations outlet pipes to an open ditch or storm drains are required for the proper functioning of the collection system. In areas of frost, special consideration must be given to prevention of the freezing of the outlets. It is recommended that a metal or rigid solid-walled pipe be used for the lateral outlet pipe to ensure the proper grade and to prevent crushing by mowing operations. To ensure water does not back into the collector system. a 3 percent slope of the pipe to the ditch and a 6-in. freeboard for the pipe invert at the outlet over the 2-year design flow in the ditch as shown in Figure 8 are recommended.

d. Outlet Structure. Where the collection system outlets on a slope as shown in Figure 8, outlet structures are recommended to provide protection of the outlet pipe, prevent slope erosion, facilitate the location of outlet pipe for maintenance, and provide rodent protection. Headwalls of the outlet structure should be placed flush with the slope so that mowing operations are not impaired. Positive grades should be provided so that the headwall apron will drain. Reference markers for the outlet structure are recommended to facilitate locating structure for maintenance or observation.

e. Manholes and Clean-outs. The provisions of TM 5-820-2/AFM 88-5, Chap. 2 should be followed as to the design and installation of manholes and clean-outs.

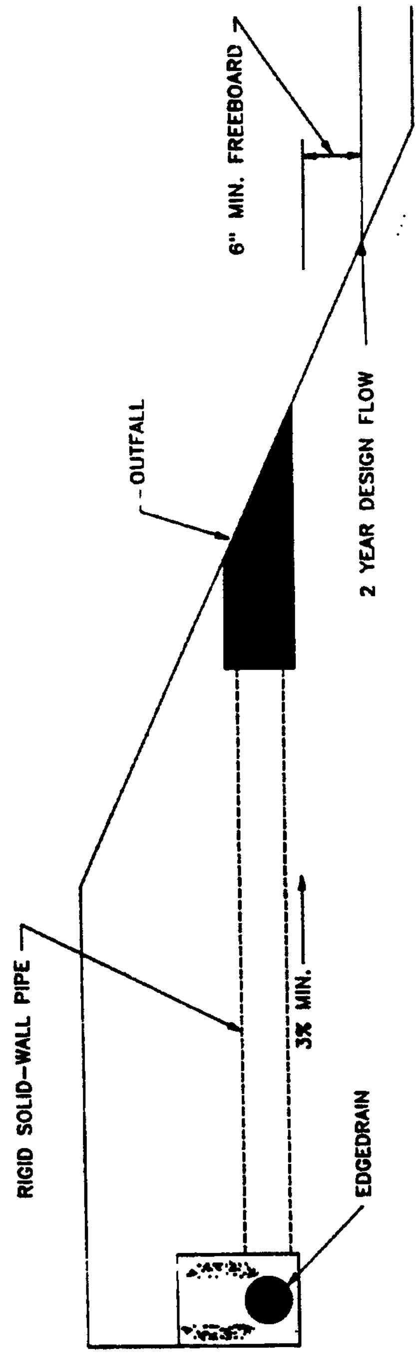


Figure 8. Outlet Pipe Design

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DEPARTMENT OF THE ARMY
(August 1989)
U.S. ARMY CORPS OF ENGINEERS

CEGS-OXXXX

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

SECTION 0XXXXX

DRAINAGE LAYER

****
NOTE: This guide specification covers the requirements for drainage layer material under roads, streets and airfield pavements. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-720.
****

PART 1 GENERAL

****
NOTE: See Additional Note A.
****

1.1 SUMMARY (Not Applicable)

****
NOTE: Paragraph "1.1 SUMMARY (Not Applicable)" is required in all CEGS in order to make CEGS compatible with guide specifications of other agencies within the SPECSINTACT system. However, this paragraph is not to be included in Corps of Engineers project specifications.
****

1.2 REFERENCES

****
NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.
****

The publications listed below form a part of this specification to the extent referenced. The publications are

referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

\-ASTM C 29-\	(1987) Unit weight and Voids in Aggregate
\-ASTM C 88-\	(1983) Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
\-ASTM C 117-\	(1987) Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by washing
\-ASTM C 131-\	(1981; R 1987) Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
\-ASTM C 136-\	(1984; Rev. A) Sieve Analysis of Fine and Coarse Aggregates
\-ASTM D 75-\	(1987) Sampling Aggregates
\-ASTM D 1556-\	(1982) Density of Soil In-Place by the Sand-Cone Method
\-ASTM D 2922-\	(1981) Density of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth)
\-ASTM D 3017-\	(1978) Moisture Content of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth)
\-ASTM E 548-\	(1984) Preparation of Criteria for Use in the Evaluation of Testing Laboratories and Inspection Bodies

\-CORPS OF ENGINEERS (COE)-\

\-COE CRD-C 119-\	\(1953: Rev Jun 1963) Flat and Elongated Particles in Coarse Aggregates\

1.3 MEASUREMENT AND PAYMENT

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****
NOTE: This paragraph shall be deleted when the work is covered by a lump-sum contract price.
****

1.3.1 Waybills and Delivery Tickets

Copies of waybills and delivery tickets shall be submitted during the progress of the work. Before the final statement is allowed, the Contractor shall file certified waybills and certified delivery tickets for all aggregates actually used.

1.3.2 Measurement

[The quantity of [drainage layer course] [and open graded choke stone] material completed and accepted will be measured in square yards.) [The quantity of drainage layer material [and open graded choke stone material] completed and accepted will be measured in cubic yards. The volume of drainage layer material in place and accepted will be determined by the average job thickness obtained in accordance with paragraph "THICKNESS CONTROL" and the dimensions indicated.) [The tonnage of drainage layer material (and open graded choke stone material] used for will be the number of 2000-pound tons of aggregate, determined by the Contracting Officer, placed and accepted. Deductions will be 'Lade for any material wasted, unused, rejected, or used for the convenience of the Contractor.)

1.3.3 Payment

1.3.3.1 Quantity of Drainage Layer Material

Quantity of drainage layer material as specified above will be paid for at the contract unit price for [drainage layer material) [and open graded choke stone), which will constitute full compensation for the construction and completion of the drainage layer, including the furnishing of all other necessary labor and incidentals.

1.4 SUBMITTALS

****
NOTE: Submittals must be limited to those necessary for adequate quality assurance. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.
Indicate submittal classification in the blank space using "GA" when the submittal requires Government approval or "FIO" when the submittal is for information only.

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Government approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section \=01300=\ SUBMITTALS:

SD-09, reports\

Certified test results.
Report of test section construction.
Results of field tests.

1.5 COMPACTION

Field compaction requirements shall be based on the results of a test section constructed by the Contractor, using the materials, methods, and equipment proposed for use in the work. The test section shall be in accordance with paragraph "TEST SECTION". The test section shall be used to establish the number of passes of a roller, the target field dry density and the moisture content required for full scale production. Field density tests shall be taken to assure that the dry density is at least 100 percent of the target dry density.

1.6 EQUIPMENT

****
NOTE: If desirable, requirements for specific types of equipment applicable to methods of construction based on local conditions will be included.
****

All plant, equipment, and tools used in the performance of the work will be subject to approval before the work is started and shall be maintained in satisfactory working condition at all times. The equipment shall be adequate to meet grade control, thickness control, smoothness and compaction requirements as set forth herein. An asphalt paving machine shall be used to place the drainage layer [and choke stone]. A hopper type base course spreader box may be used if it can be demonstrated that the spreader box can be operated to obtain the specified results. Compaction shall be accomplished by using a 10 to 15 ton dual or single smooth drum vibratory roller.

1.7 Weather Limitation

Drainage layer material shall be placed when the atmospheric temperature is above 35 degrees F. Areas of completed drainage layer that are damaged by freezing, rainfall, or other weather conditions or by contamination from sediments, dust, dirt, or foreign material shall be corrected to meet specified requirements.

1.8 SAMPLING AND TESTING

Sampling and testing shall be the responsibility of the Contractor. Sampling and testing shall be performed by an approved commercial testing laboratory, or by the Contractor subject to approval. If the Contractor elects to establish testing facilities of his own, approval of such facilities shall be based on compliance with \-ASTM E 548-\, and no work requiring testing will be permitted until the Contractor's facilities have been inspected and approved. The first inspection of the facilities shall be at the expense of the Government and any subsequent inspections required because of failure of the first inspection will be at the expense of the Contractor. Such costs will be deducted from the total amount due the Contractor. The materials shall be tested to establish compliance with the specified requirements. Copies of test results shall be furnished to the Contracting Officer.

1.8.1 Samples

Samples for testing shall be taken in conformance with \-ASTM D 75-\. When deemed necessary, the sampling will be observed by the Contracting Officer.

1.8.2 Tests

The following tests shall be performed in conformance with the applicable standards listed.

1.8.2.1 \+Sieve Analyses+\

Sieve analyses shall be made in conformance with \-ASTM C 117-\ and \-ASTM C 136-\.

1.8.2.2 \+Density Tests+\

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Density shall be measured in the field in accordance with \-ASTM D 1556-\ \-ASTM D 2922-\. For the method presented in \-ASTM D 1556-\ the base plate as shown in the drawing shall be used. For the method presented in \-ASTM D 2922-\ the calibration curves shall be checked and adjusted if necessary using only the sand cone method as described in paragraph "Calibration" of the ASTM publication. Tests performed in accordance with \-ASTM D 2922-\ results in a wet unit weight of soil and when using this method, \-ASTM D 3017-\ shall be used to determine the moisture content of the soil. The calibration curves furnished with the moisture gauges shall also be checked along with density calibration checks as described in \-ASTM D 3017-\. The calibration checks of both the density and moisture gauges shall be made by the prepared containers of material method, as described in paragraph "Calibration" of \-ASTM D 2922-\, on each different type of material being tested at the beginning of a job and at intervals as directed.

1.8.2.3 \+Soundness Test+\

Soundness tests shall be made in conformance with \-ASTM C 88-\.

1.8.2.4 \+Los Angeles Abrasion Test+\

Los Angeles abrasion tests shall be made in conformance with \-ASTM C 131-\.

1.8.2.5 \+Flat or Elongated Particles Tests+\

Flat and/or elongated particles tests shall be performed in accordance with \-CRD-C 119-\.

1.8.2.6 \-Fractured Faces Tests-\

When aggregates are supplied from crushed gravel, the aggregate shall meet the requirements for fractured faces in paragraph "AGGREGATES".

****

NOTE: Field density tests and laboratory tests are generally performed at a frequency of one set of tests for every 1000 square yards of completed area. Other frequency intervals may be specified when conditions warrant. It is important that both field density tests and laboratory tests be conducted on the same materials.

****

1.8.3 Testing Frequency

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Sieve analyses and field density tests shall be performed at a rate of at least 1 test for every (1000] square yards of completed area and not less than 1 test for each days production. Soundness tests, Los Angeles abrasion tests, fractured faces tests and flat and/or elongated particles tests shall be performed at the rate of 1 test for every [10] density tests.

1.8.4 Approval of Material

The source of the material to be used for producing aggregates shall be selected [_____) days prior to the time the material will be required in the test section. Approval of both the source and the material will be based on test section performance and tests for gradation, soundness, Los Angeles abrasion flat and/or elongated particles tests and fractured faces tests performed on samples taken from the completed and compacted drainage layer course.

PART 2 PRODUCTS

2.1 AGGREGATES

Aggregates shall consist of clean, sound, hard durable particles of crushed stone, crushed slag, or crushed gravel. The Contractor shall obtain materials that meet the specification and can be used to meet the grade and smoothness requirements specified herein, after all compaction (and proof-rolling] operations have been completed. Slag shall be an air-cooled, blast-furnace product having a dry weight of not less than 65 pcf as determined by \-ASTM C 29-\. The aggregates shall be free of silt and clay as defined by \-ASTM D 2487-\, vegetable matter, and other objectionable materials or coatings.

2.1.1 Quality

****
NOTE: The percentages of loss and soundness applicable to the specific job will be specified. A loss value of 40 will be used except that a value up to 50 percent may be used where local experience indicates that the material is satisfactory. The soundness test is for use in excluding aggregates known to be unsatisfactory and for evaluating aggregates from new sources. The Designer will insert in the blank space the applicable loss in percent for the specific job based on the knowledge of both coarse and fine aggregates in the area that have been previously approved and have a satisfactory service

record for at least 5 years. The values in contract specifications will insure that aggregates from new sources will be equal to or better than aggregates from known or approved sources. The percent of fractured faces may be reduced to 75% if the required CBR is 50 or less.
****
Aggregates shall be angular particles of uniform density. The aggregate shall have a loss not greater than [_____) percent weighted averaged at five cycles when tested for soundness in magnesium sulfate in accordance with \-ASTM C 88-\. The aggregate shall have a percentage of loss on abrasion not to exceed [_____] after 500 revolutions as determined by \-ASTM C 131-\. The percentage of flat and/or elongated particles as determined by \-CRD-C 119-\ shall not exceed 20 in the fraction retained on the ½-inch sieve, in the fraction passing the ½-inch sieve but retained on the #4 sieve and in the percent passing the #4 sieve but retained on the #16 sieve. A flat particle is one having a ratio of width to thickness greater than 3: an elongated particle is one having a ratio of length to width greater than 3. When the aggregate is supplied from more than one source, aggregate from each source shall meet the requirements set forth herein. When the aggregate is supplied from crushed gravel it shall be manufactured from gravel particles 90 percent of which by weight are retained on the maximum-size sieve listed in TABLE I. In the portion retained on each sieve specified, the crushed gravel shall contain at least 90 percent by weight of crushed pieces having two or more freshly fractured faces with the area of each face being at least equal to 75 percent of the smallest midsectional area of the face. When two fractures are contiguous, the angle between planes of the fractures must be at least 30 degrees in order to count as two fractured faces.

2.1.2 Gradation Requirements

****
NOTE: The gradation or gradations applicable to the specific job will be specified. The designer shall select gradation A or B depending on the required permeability. Both gradations should not be in the contract documents. Gradation A should provide a permeability greater than 1000 feet per day. Gradation B should provide a permeability of greater than 5000 feet per day. Gradation A is well graded enough to be stable to work on, however gradation B will require the choke stone to lock the surface together to provide a stable working platform. If experience with aggregates in the project area indicates that they break down during compaction, then the designer should consider using the cement or asphalt stabilized drainage layer.

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When editing the specification, take the A or B designation off the gradation, unless both gradations are used. The maximum size of aggregates will be specified in the blank space. The gradation for the open graded choke stone matches ASTM gradation No. 8.
****

Gradation requirements specified herein shall apply to the completed drainage layer course. The aggregates shall have a maximum size of [_____) inch(e's) and be well graded within the limits specified in TABLE I.

TABLE I. GRADATION OF DRAINAGE LAYER MATERIAL
(See Notes 1-3)

Percentage by Weight Passing Square-Mesh Sieve

Sieve Designation	**Drainage Layer Gradation[A]**	**Drainage Layer Gradation[B]**	**Open Graded Choke Stone**
1-1/2 inch	**100**	**100**	**100**
1 inch	**70-100**	**95-100**	**100**
3/4 inch	**55-100**	**---**	**100**
1/2 inch	**40-80**	**25-80**	**100**
3/8 inch	**30-65**	**---**	**80-100**
No. 4	**10-50**	**0-10**	**10-100**
No. 8	**0-25**	**0-2**	**0-40**
No. 16	**0-5**	**---**	**0-10**

NOTE 1: Particles having diameters less than 0.02 mm shall not be in excess of 1.5 percent by weight of the total sample tested.

NOTE 2: The values are based on aggregates of uniform specific gravity, and the percentages passing the various sieves may require appropriate correction by the Contracting Officer when aggregates of varying specific gravities are used.

****
Select the first Note 3 if gradation A is used and select the second Note 3 if gradation B is used.
****

[NOTE 3: For the specified gradation the coefficient of uniformity (CU) shall be greater than 3.5 (CU = D_{60}/D_{10}).]

[NOTE 3: Choke stone will be required to stabilize the top surface of the drainage layer material. The choke stone shall

be a small size stone made up of hard, durable crushed aggregate having 90 percent of the stone with fractured faces. The gradation for the choke stone shall be based on the gradation of the material submitted for use as drainage layer material, using the following criteria:

1. The ratio of the D_{15} of the drainage layer material to the D_{15} of the choke stone must be less than 5.

2. The ratio of the D_{50} of the drainage layer material to the D_{50} of the choke stone must be greater than 2.]

PART 3 EXECUTION

3.1 OPERATION OF AGGREGATE SOURCES

Clearing, stripping, and excavating shall be the responsibility of the Contractor. The aggregate sources shall be operated in such a manner as to produce the quantity and quality of drainage layer materials meeting these specification requirements in the specified time limits. Upon completion of the work, the aggregate sources on private lands shall be conditioned in agreement with local laws or authorities.

3.2 STOCKPILING MATERIAL

Prior to stockpiling of material, storage sites shall be cleared and leveled by the Contractor. All materials, shall be stockpiled in a manner so as to prevent segregation and at the locations designated by the Contracting Officer. Materials obtained from different sources shall be stockpiled separately.

3.3 TEST SECTION

3.3.1 General

The test section shall be used to evaluate the trafficability and constructibility of the drainage layer material as well as to determine the required mixing, placement, and compaction procedures. Test section data shall be used to determine the required number of passes, the optimum moisture content, the target dry density and the need for a final static pass of the roller (without vibration) to smooth the drainage layer surface.

3.3.2 Scheduling

The test section shall be constructed a minimum of [30) days

prior to the start of paving operations to provide sufficient time for an evaluation of the proposed materials, equipment and procedures including Government QA testing.

3.3.3 Location and Size

The test strip shall be placed outside the production paving areas in an area with similar subgrade conditions approved by the Contracting Officer. The underlying courses and subgrade preparation, required for the pavement section, shall be completed, inspected and approved in the test section prior to placing the drainage layer. The test section shall be a minimum of (100) feet long and one full paving lane wide.

3.3.4 Initial Testing

Certified test results, to verify the materials proposed for use in the test section meet the contract requirements in paragraph "AGGREGATES", shall be provided by the contractor at his expense, and approved by the Contracting Officer prior to the start of the test strip.

3.3.5 Mixing and Placement

Mixing of aggregate blends shall be performed by a central pugmill type mixer and delivered to the site. Placement shall be accomplished by using an asphalt paving machine meeting the requirements in paragraph "EQUIPMENT".

3.3.6 Compaction

Compaction shall be accomplished by using a vibratory roller meeting the requirements of paragraph "EQUIPMENT" and operating at a maximum rolling speed of 1.5 miles per hour.

3.3.7 Procedure

The test section shall be divided into three subsections of different aggregate water contents to help establish a correlation between aggregate water content, the number of roller passes, and the target dry density to be achieved in the field. Density and moisture content tests shall be conducted at the surface and at intervals of 2 inches of depth down for the total layer thickness, using calibrated nuclear density gauges. A sieve analysis test shall be conducted on a composite sample, taken adjacent to the density test locations, which represents the total layer thickness. One set of tests shall be taken before compaction and after each subsequent compaction pass in each subsection. Compaction passes and density readings shall continue until the difference between the average dry densities of any two consecutive passes is less than or equal to 0.5 pcf.

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The test section shall be completed by making one final pass with the roller in the static mode and observing the change in the drainage layer surface texture.

\+3.3.8 Evaluation+\

Within 10 days of completion of the test:section, the contractor shall submit to the contracting officer the Test Section Construction Report complete with all of the data from the required testing. The contracting officer shall evaluate the data and provide to the contractor the required number of passes of the roller, the target dry density and moisture content for field density testing during construction, the depth at which to check the moisture and density, and the need for a static pass of the roller.

****
The evaluation of the data from the test section shall be accomplished by the district designer. The evaluation should be based on trying to achieve maximum density in the drainage layer without excessive crushing of the aggregates during compaction. The harder and more durable the aggregate the more compaction effort it can withstand. To evaluate the test fill data it is suggested that the in-place density and percent passing the No. 4 and No. 16 sieve sizes should be plotted against cumulative passes. With these results the designer should try to optimize dry density while minimizing aggregate degradation. Generally after between 3 and 6 passes, only slight increases in dry density will be achieved (0.5 pcf). At this point the measured field density is at or near the maximum density obtainable for this material, for the given field conditions. The target dry density should then be set slightly lower than this maximum field dry density. At is suggested that the target dry density be set at 98 percent of the maximum density obtained in the test section. The data on the percent passing should be looked at closely to determine if degradation of the aggregate is occurring. If the percent passing the given sieve sizes is increasing, then the aggregate is being broken down by the compaction effort. If this is occurring, selection of a target field density will be more difficult. The target field density selected will have to be balanced between aggregate degradation, dry density and stability of the drainage layer surface. Stability of the layer surface should take precedence.
****

3.4 PREPARATION OF UNDERLYING COURSE

****

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NOTE: Only the reference to the specification section that covers the preparation of underlying course for the particular project will be retained; other references will be deleted. The surface of a cohesionless underlying courses may require stabilization prior to placement of the drainage layer course. This may be accomplished by compacting a layer of crushed aggregate into the surface. It may also be obtained by methods based on local experience. These methods (e.g., use of cement, lime, bitumen, and chemicals), as well as any stabilization of cohesive materials, will be subject to approval by HQUSACE (CEMP-ET). The additional crushed aggregate will be considered as part of the underlying course and may be paid for or included in the specification section that covers the preparation of that particular course for the particular project.
****

Prior to constructing the drainage layer, the underlying course shall be cleaned of all foreign substances. During construction the underlying course shall contain no frozen material. The underlying course shall conform to [Section \=02230=\ EXCAVATION, EMBANKMENT, AND PREPARATION OF SUBGRADE FOR RAILROADS AND ROADWAYS] [Section \-02234-\ SUBBASE COURSE] [Section \-02232-\ SELECT-MATERIAL SUBBASE COURSE]. Ruts or soft, yielding spots in the underlying courses, areas having inadequate compaction, and deviations of the surface from the requirements set forth herein shall be corrected by loosening and removing soft or unsatisfactory laterial and by adding approved material, reshaping to line and grade, and recompacting to specified density requirements. The finished underlying course shall not be disturbed by traffic or other operations and shall be maintained by the Contractor in a satisfactory condition until the drainage layer is placed.

3.5 GRADE CONTROL

During construction, the lines and grades including crown and cross slope indicated for the drainage layer course shall be maintained by means of line and grade stakes placed by the Contractor.

3.6 MIXING AND PLACING

The drainage layer material shall be placed on the underlying course in lifts of uniform thickness with an asphalt paving machine or an approved hopper type base course spreader box. When a compacted layer 6 inches or less in thickness is required, the material shall be placed in a single lift. When a compacted layer in excess of 6 inches is required, the material shall be placed in lifts of equal thickness. No lift shall exceed 6 inches or be less than 3 inches when

compacted. The lifts shall be so placed that when compacted they will be true to the grades or levels required with the least possible surface disturbance. Where the drainage layer is placed in more than one lift, the previously constructed lift shall be cleaned of loose and foreign matter. Such adjustments in placing procedures or equipment shall be made to obtain true grades, to minimize segregation and degradation, to adjust the water content, and to insure an acceptable drainage layer.

3.7 COMPACTION

3.7.1 Requirements

****
NOTE: Cohesionless materials are generally free-draining, and the highest practicable water content is limited by the amount of water the material will retain, as is usually evidenced by free water draining from the mold during compaction. The words in brackets will be included only if the drainage layer material is used for shoulders.
****

Compaction shall be accomplished by using a 10 to 15 ton dual or single smooth drum vibratory roller operating at a maximum rolling speed of 1.5 miles per hour. Each lift of drainage material [including shoulders] shall be compacted with the number of passes of the roller as determined by the test section. A field dry density of at least 100 percent of target field dry density determined from the test section is required. If the required field dry density is not obtained, the number of roller passes shall be adjusted in accordance with paragraph DEFICIENCIES. Water content shall be maintained during the compaction procedure such that the water Content will be within plus or minus 2 percent of the optimum water content determined by the test section. In all places not accessible to the rollers, the drainage layer material shall be compacted with mechanical hand operated tampers.

3.8 Finishing

****
Select the appropriate paragraph or paragraphs below. The first paragraph is to be used if Gradation A is used. The first and second paragraphs are to be used if Gradation B is used.
****

3.8.1 Finishing Drainage Layer Material. The top surface of the drainage layer shall be finished after final compaction as determined from the test section. Adjustments in rolling and finishing procedures shall be made to obtain grades, to

minimize segregation and degradation of the drainage layer material, to adjust the water content, and to insure an acceptable drainage layer.

[3.8.2 Choke Stone Placement. After final compaction, the surface of the drainage layer material shall be stabilized by a thin layer of choke stone. The layer thickness shall not be greater than ½ inch and shall be spread using a paver or spreader box. The choke stone shall beworked into the surface of the drainage layer material by the use of a vibratory roller and by wetting. The choke stone shall be considered as part of drainage layer thickness, and shall not be measured separately.3

3.9 PROOF ROLLING

****
NOTE: Drainage layer material will not require proof rolling. For airfield pavements, proof rolling will be required on base or subbase course layers above and below the drainage layer. That proof rolling should be covered in the appropriate specification section.
****

Proof rolling of the drainage layer shall not be required.

3.10 EDGES OF DRAINAGE LAYER

Material shall be placed along the edges of the drainage layer in such quantity as will compact to the thickness of the layer being constructed. When the drainage material layer is being constructed in two or more lifts, at least a 1-foot width of the shoulder shall be rolled and compacted simultaneously with the rolling and compacting of each lift of the drainage material course.

3.11 \+SMOOTHNESS TEST+\

****
NOTE: A 12-foot straightedge with the deviations unchanged may be specified instead of a 10-foot straightedge.
****

The surface of the top layer shall not deviate more than 3/8 inch when tested with a 10-foot straightedge applied parallel

with and at right angles to the centerline of the area to be paved. Deviations exceeding 3/8 inch shall be corrected in accordance with paragraph DEFICIENCIES.

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3.12 THICKNESS CONTROL

The completed thickness of the drainage layer course shall be within 1/2 inch of the thickness indicated. The thickness of the drainage layer course shall be measured at intervals providing at least one measurement for each 500 square yards of drainage layer. The depth measurement shall be made by test holes at least 3 inches in diameter. Where the measured thickness of the drainage layer is more than ½ inch deficient, such areas shall be corrected in accordance with paragraph DEFICIENCIES. Where the measured thickness of the drainage layer is 1/2 inch more than indicated, it will be considered as conforming with the requirements plus ½ inch, provided the surface of the drainage layer is within ½ inch of established grade. The average job thickness shall be the average of all job measurements as specified above but within ¼ inch of the thickness shown on the drawings.

3.13 DEFICIENCIES

3.13.1 Grade, and Thickness

Deficiencies in grade and thickness shall be corrected such that both grade and thickness tolerances are met. In no case will thin layers of material be added to the top surface of the drainage layer to meet grade or increase thickness. If the elevation of the top of the drainage layer is more than ½ inch above the plan grade it shall be trimmed to grade and finished in accordance with paragraph FINISHING. If the elevation of the top surface of the drainage layer is ½ inch or more below the required grade, the surface of the drainage layer shall be scarified to a depth of at least 3 inches, new material shall be added, and the layer shall be blended and recompacted to bring it to grade. Where the measured thickness of the drainage layer is more than ½ deficient, such areas shall be corrected by excavating to the required depth and replacing with new material with a minimum compacted lift thickness of at least 3 inches. The depth of required excavation shall be controlled to keep the final surface elevation within grade requirements and to preserve layer thicknesses of materials below the drainage layer.

3.13.2 Density

Density shall be considered deficient if the field dry density test results are below 100 percent of the target dry density.

If the densities are deficient, then the layer shall be rolled with 2 additional passes of the specified roller. If the dry density is still deficient, then work will be stopped until the cause of the low dry densities can be determined by the Contracting Officer.

3.13.3 Smoothness

Deficiencies in smoothness shall be corrected as if they are deficiencies in grade or thickness. All tolerances for grade and thickness must be maintained while correcting smoothness deficiencies.

3.14 MAINTENANCE

The drainage layer shall be maintained in a condition that will meet all specification requirements until accepted.
****

ADDITIONAL NOTES

NOTE A: For additional information on the use of all CEGS, see CEGS-0100\00 CEGS GENERAL NOTES.

****

-- End of Section --